Interim Reclamation Success Analysis North and South Paquate Open Pits Jackpile-Paquate Uranium Mine

Lewis Munk and Paul Boden

Executive Summary

The goal in mine reclamation is to stabilize the mined-area from accelerated erosion and to return the lands to a reasonable level of productivity. The secondary goal at the Jackpile-Paquate Mine is to restrict the environmental exposure of the protore, or low grade uranium ore, exposed by mining. The Record of Decision (ROD) for the Jackpile-Paquate Uranium Mine established reclamation success standards for the mined area. The vegetative parameters evaluated include foliar cover, basal cover, frequency, plant density, and productivity. The reclamation is considered successful after 10 years, and when the reclaimed areas vegetative attributes are within 90 percent of the reference area. The ROD did not specify the level of statistical accuracy of the vegetation data nor the key components for comparison (e.g., annual vs. perennial grasses). This document details the interim reclamation status of the NPOP-20, SPOP-34, and SPOP-35 pit bottoms in the North and South Paquate mine area three years after the initial seeding.

In general, reclamation in the pit bottoms can be considered successful in meeting the goals of landscape stability, productivity, and containment of the protore. The pit bottoms are dominated by vigorous and productive perennial grasses with both cool- and warm-season character, and contain a desirable mixture of shrubs. The forb component in the pit bottoms contains some undesirable species that are typical of early successional stages (e.g., Kochia and tumbleweed). These forb species are expected to decrease in frequency with time.

Although the reclamation can generally be considered successful not all the vegetative parameters in the pit bottoms conform to the numerical standards required by ROD when compared to the reference area (Table below). In particular, foliar and basal cover in the NPOP-20 pit bottom and plant density in all the pits is less than 90% of the reference area. The use of reference areas as a reclamation standard is complicated by the lack of a model reference area with ideal site characteristics. Thus, the reclamation success is obscured by these simple single parameter statistical comparisons because of differences in the vegetative composition among the reclaimed and reference areas. For instance, less desirable annual grasses contribute significantly to the total foliar cover in the reference area, but are only minor representatives in the reclaimed areas.

Summary statistics for mean foliar cover, basal cover, annual production, and plant density for the reclaimed pit bottoms and references areas.† Jackpile\Paquate Uranium Mine, Laguna Pueblo, NM.

	Total Cover				Basal Cover				Annual	Plant
Location	Foliar	Rock	Litter	Bare Soil	Veg.	Rock	Litter	Bare Soil	Production	Density
	Percent Cover								lbs/ac	ind/m^2
NPOP-20	32.9	1.2	0.6	65.3	5.3	1.9	0.8	92.0	496	22.6
SPOP-34	47.6	1.5	1.7	49.2	7.6	1.5	1.7	89.2	531	15.0
SPOP-35	47.4	0.5	1.1	51.0	6.3	0.5	2.0	91.2	783	22.3
Ref. Areas	50.4	0.5	4.2	44.8	7.4	0.6	7.9	84.1	328	38.0

† Annual production of perennial grasses on air-dry basis in pounds/acre.

In conclusion, the reclamation in the pit bottoms is considered successful with respect to meeting the primary goals of landscape stabilization, productivity, and protore containment, even though, it does not meet the strict numerical requirements of the ROD for some parameters.

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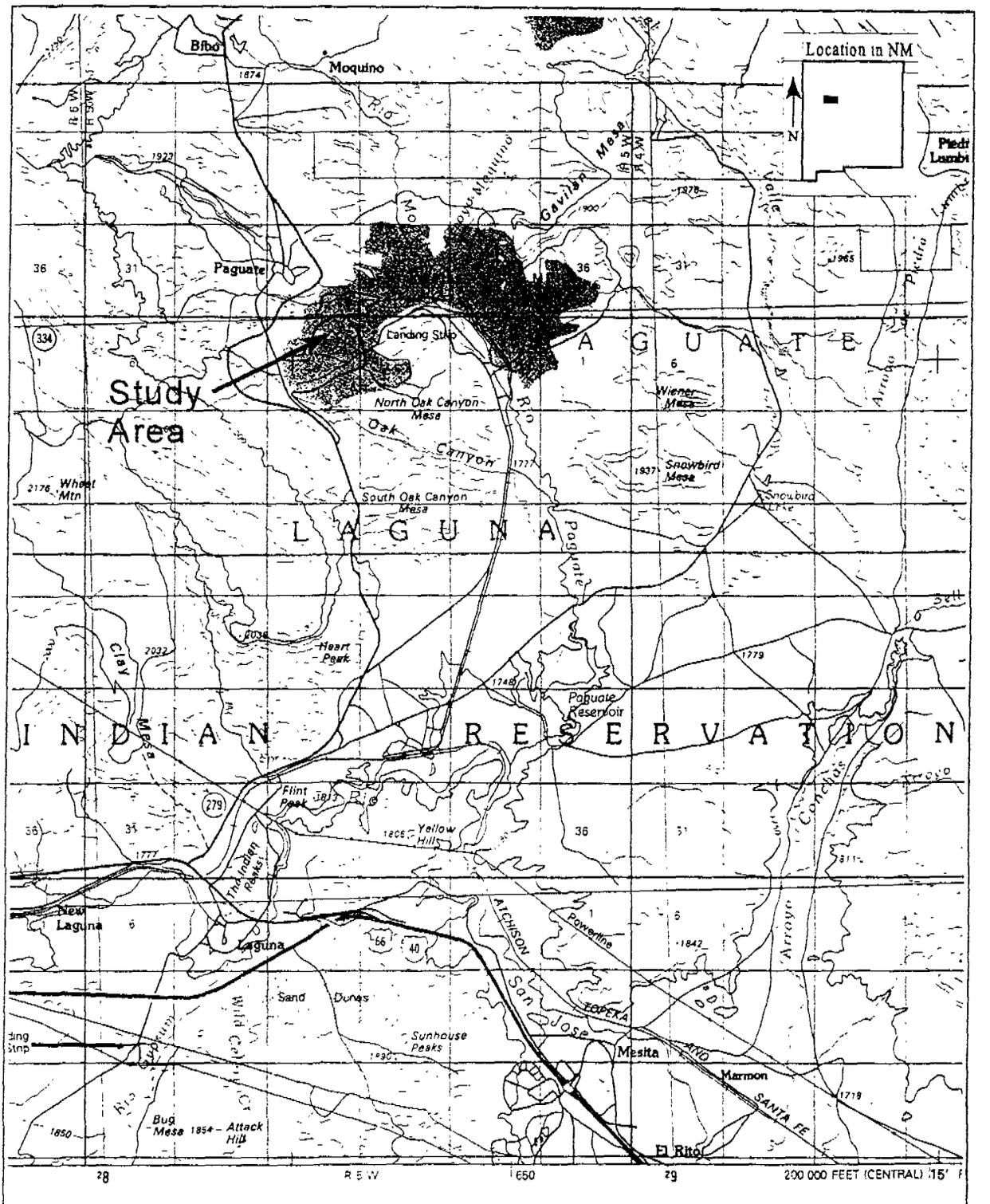
1.0 Introduction

The Jackpile-Paquate Uranium Mine is located on Laguna Pueblo lands about 40 miles west of Albuquerque, New Mexico (Fig. 1). The Anaconda Minerals Company operated what was the largest uranium mine in the world for 29 years before closing in 1982. The need for reclamation of the mine was identified in an Environmental Impact Statement (EIS) in 1986 (DOI, 1986a). The Record of Decision (ROD) for the Jackpile-Paquate Uranium Mine Reclamation Project followed the EIS and specified requirements for reclamation (DOI, 1986b). The ROD required vegetation monitoring to evaluate the success of the reclamation efforts. Thus, this document presents results of an interim evaluation of the vegetative conditions in the three pit bottoms in the North and South Paquate area (Fig. 2). Specifically, the pit bottoms investigated include the North Paquate Open Pit (NPOP-20), and two open pits in the South Paquate area (SPOP-34 and SPOP-35).

1.1 Reclamation Success Criteria

Vegetation monitoring requires the collection of data for foliar cover, basal cover, density, frequency, and annual production. These data are compared to measurements taken from a reference area to determine if the reclamation is successful. The reclamation is considered successful when the vegetative density, frequency, foliar and basal cover, and production on the reclaimed sites is at least 90 percent of the undisturbed reference areas (DOI, 1986b). However, final release of the reclaimed areas will not occur sooner than 10 years after seeding, even though the reclaimed areas may meet or exceed the success criteria. Periodic monitoring of the reclaimed areas is important to determine the likelihood of achieving the reclamation standards and the need for potential interim corrective measures. The intent of the reclamation is to return the mined lands to a reasonably productive and ecologically stable state. The use of reference areas as a standards for comparison, is based on theory that the reference area represents the desired future condition for the reclaimed areas. In reality, it is difficult to find ecologically stable reference areas.



Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure 1. Location of the Jackpile/Paquate Uranium Mine. Laguna Pueblo, New Mexico.
December 1996	Adapted from Grants Quadrangle (1:100,000 scale series)

Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure 2. Location of the reclaimed Pit Bottoms and Reference Areas at the Jackpile/Paquate *Uranium Mine, Laguna Pueblo, New Mexico.*
December 1996	Adapted from 8-14-96 Air Photo; Approximate Scale 1:33,000

2.0 Methods

The ROD provided requirements for reclamation success, but did not identify the specific data collection methods. This study was conducted using methods that conform to generally accepted mine reclamation monitoring standards. The field work was preformed by Lewis Munk and Paul Boden and was conducted between 26 September and 17 October 1996. A transect/quadrat system was used as the framework to collect the foliar cover, basal cover, density, and frequency data. Annual production was determined by clipping and weighing. The methods used in this investigation are detailed below.

2.1 Plot, Transect, and Quadrat Location

The vegetation sampling plots were randomly located in the pit bottoms and reference area using a grid-overlay on aerial photos (Appendix, Figures A1-A5). The vegetation plots were 38 m (125 ft) square and were selected for sampling using a list of random coordinates. Plots that occurred partially on the pit high walls were excluded from analysis. Two 15 m transects were located in each grid in a dog-leg pattern, with the transects originating in the southeast corner of the vegetation plot (Fig. 3). Three square-shaped quadrats (1 m^2) were placed at five meter intervals along each transect starting at the 3 m interval (Fig. 3). One of the six quadrats in each plot was randomly selected for clipping to determine annual production.

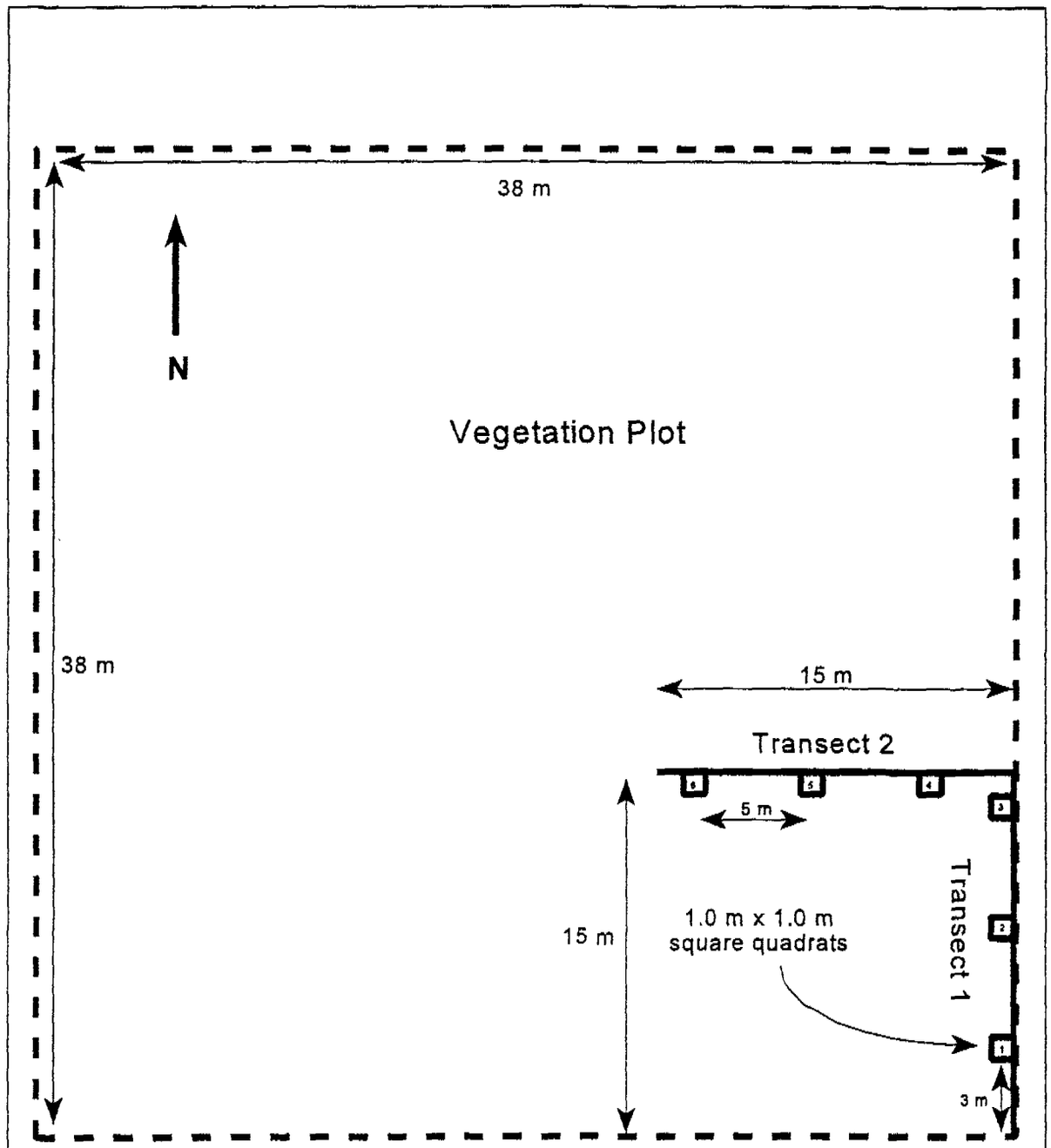
2.2 Species Occurrence, Frequency, and Density

Species occurrence was determined by traversing the vegetation plot and listing the species encountered. Frequency was determined on a species-basis by counting the number of individual plants in the quadrats. Density, or the number of plants/m^2, was determined by dividing the total number of plants by the number of quadrats measured.

2.3 Annual Production

The annual production of perennial grasses was determined by clipping the current years growth within the vertical confines of a quadrat. The grasses were clipped to within about 5 cm of the soil surface, and the current years growth was segregated from the previous years growth. The plant tissue was placed in labeled and tared paper bags, and the tissue was air-dried (7-14 days) until no weight change was observed with repeated measurements. Quadrats with no perennial grasses were considered to have zero annual production. Forbs, annual grasses, and shrubs were not included in the productivity measurements. Thus, the productivity measurements reported in this study underestimate the total biomass production for the areas investigated. The net weight of the air-dried vegetation was converted to a lbs/ac basis using the following formula:

lbs/ac perennial biomass = (grams air-dried vegetation)(0.89).



Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure 3. Vegetation plot, transect, and quadrat dimensions and layout for the Jackpile-Paquate Uranium Mine vegetation monitoring study.
20 December 1996	Approximate Scale 1" = 20' ; 1 cm = 2.4 m

2.4 Cover and Frequency

Relative and total foliar cover, basal cover, surface litter, surface rock fragments, and bare soil were determined by ocular estimates using the cover classes defined in Table 1. Percent-area cards were used to increase the accuracy and consistency of the cover estimates. In this study, foliar cover was defined as the percentage of quadrat area included in the vertical projection of the canopy. The foliar cover estimates included the foliage interspaces of all individuals rooted in the quadrats. The foliar cover estimates made on a species basis represent relative cover percentages, and the sum for an individual quadrat may exceed 100 percent in multi-layered canopies. In contrast, the total foliar cover estimate did not include the contribution from individuals in multi-layered canopies. Thus, the sum of the total foliar cover, surface litter, rock fragments, and bare soil will not exceed 100 percent. Basal cover was defined as the proportion of the ground occupied by the crowns of grasses and rooting stems of forbs and shrubs. In addition, basal cover estimates were made for surface litter, rock fragments, and bare soil. Like the total cover estimates, the basal cover estimates sum to 100 percent.

Table 1. Cover classes used for foliar cover and basal cover estimates at the Jackpile/Paquate Uranium Mine.[†]

Class	Cover	Mid-point	Class	Cover	Mid-point
	%	%		%	%
1	0-1	0.5	8	35-45	40
2	1-3	2.0	9	45-55	50
3	3-5	4.0	10	55-65	60
4	5-10	7.5	11	65-75	70
5	10-15	12.5	12	75-85	80
6	15-25	20	13	85-95	90
7	25-35	30	14	95-100	97.5

[†] Note mid-point values are used in the statistical analyses.

2.5 Sample Adequacy

Since it is impossible to measure every plant in a large area, sample measurements were taken from many locations in the study area and analyzed statistically. The number of samples required to characterize a particular parameter depends on the uniformity of the vegetation and the desired degree of certainty required for the analysis. In this study sample adequacy was determined using the equation:

$$N_{min} = (t^2 s)/(dX)^2 \text{ where,}$$

N_{min} = minimum number of quadrats or samples required,
t = 1-tailed t-value for appropriate confidence interval,
s = the sample variance,
d = desired change in the mean.
X = the sample mean.

The target level of certainty in the statistical analysis is a 90 % confidence limit on plus or minus 10 % of the mean.

The sample numbers required for this level of certainty varied with the property measured and the study area. Statistical methods that rely on the Student's t values are based on the assumption that the sample data are normally distributed. With few exceptions, the data collected in this study are not normally distributed and this statistical analysis method may not be appropriate(Green, 1979). Nonetheless, this method was used since it is generally accepted in mine reclamation studies. We were unable to meet the statistical sample number requirements for annual production and plant frequency, because of time and budgetary constraints. Thus, in some areas the annual production and frequency estimates are less reliable from a statistical perspective than the foliar and basal cover estimates. The reduced level of statistical reliability detracts from the interpretation of the data, but does not invalidate the conclusions. For comparative purposes, the statistical reliability is reported as the percentage of the mean that is estimated at the 90% confidence interval in all cases.

2.6 Reference Area Selection

The vegetative characteristics of the pit bottoms are compared to reference area to determine whether the reclamation is successful. Environmental conditions (e.g., soils, slope gradient, aspect, and geomorphic position) influence the site productivity and plant community composition. Thus, the reference area site characteristics should match the reclaimed area characteristics as closely as possible. The reference area selection criteria included sites with grass-shrub cover, deep soils, nearly level slopes, and that occur in alluvial valley and fan-terrace positions that may receive run-on. Since historically ungrazed sites with these characteristics do not exist, the secondary criteria included sites with little or no evidence of recent grazing by domestic livestock. Two reference areas were selected including, 1) the high terrace of the Rio Paquate near the old housing area, and 2) the high terraces and fan remnants of the stream draining Oak Canyon (Fig. 2). It should be noted vegetation data from these reference areas would not be appropriate for evaluating the ridgetop and sideslope reclamation units at the Jackpile-Paquate Uranium Mine.

2.7 Soil Descriptions

Soil descriptions were made to characterize selected soil properties in the reference areas and pit bottoms. The soils in the reference areas (3 soil pits) were described from shallow pits and auger excavations. The pit bottom soils (24 soil pits) were described in backhoe excavations. The intent of the soil investigation was to evaluate the available water holding capacity, drainage conditions and general character of the soils, thus, the descriptions are not detailed. Soil depth, color, texture, rock fragment content, and effervescence were described for each soil pit (Soil Survey Staff, 1993).

2.8 Pit Bottom and Reference Area Characteristics

The general site characteristics of the reclaimed pit bottoms and reference areas are compared in Table 2. Figures 3-7 are photographs of representative sites in the study area. Abbreviated soil descriptions are located in the appendix (Tables A-A2). The pit bottoms are considered closed basin landforms since they have no external drainage.

Unfortunately, no natural closed basins were available as reference areas and alluvial landforms were selected instead, since they are likely to receive surface run-on. With few exceptions the soils in the pit bottoms and reference areas are well-drained, and deep or very deep. Minor depressional areas occur in the pit bottoms associated with localized subsidence. The ponding in the pit bottoms is associated with restricted permeability of the surface materials rather than a shallow water table. In general, the available water holding capacity (AWHC) and productive potential of the reference area soils is high, and these sites provide a stringent standard for comparison. The reference areas have been grazed in the past, but there was little evidence of recent grazing prior to the vegetation sampling. Grazing has probably caused shifts in the vegetative composition in the reference areas making them less than ideal. Nonetheless, they provide a reasonable standard for comparison for the reclaimed areas.

Table 2. Site characteristics of the reclaimed pit bottoms and reference area at the Jackpile/Paquate Uranium Mine.

Location	Size	Landform	Physiography	Effective Soil Depth	AWHC
	acres			inches	in./profile
Ref Areas	90	Fan terraces/uplands	Nearly level-minor depressions	60+	9.0-10.1
NPOP-20	65	Closed basin/uplands	Nearly level-minor depressions	20-60+	2.9-9.2
SPOP-34	21	Closed basin	Nearly level-minor depressions	60+	4.7-6.2
SPOP-35	18	Closed basin	Nearly level-minor depressions	29-60+	5.7-9.7

Figure 4. View of the NPOP-20 pit bottom. Shrub grass vegetation in foreground and wetland area in center of photo. View to the east from the berm on western end of the pit.

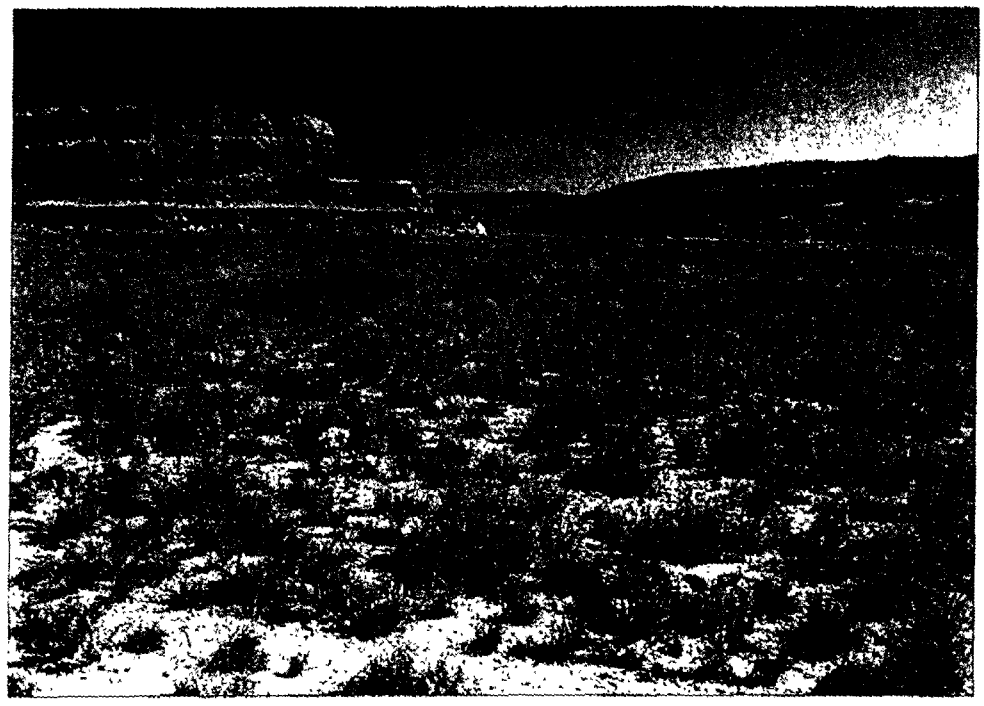


Figure 5. Grass-shrub vegetation of the SPOP-35 pit bottom. Blue grama, winterfat, and fourwing saltbush in the foreground. A stand of sideoats grama dominates the background. View to the east from the center of the pit.

Figure 6. Grass-shrub vegetation of the SPOP-35 pit bottom. Note the high density of shrubs compared to other areas. View to the northeast from the southern end of the pit.

Figure 7. Typical vegetation in the reference area. Photo taken from reference area 1, near the old housing area. View to the north.

3.0 Results and Discussion

3.1 Species Occurrence

The plant species identified in the pit bottoms and reference area are listed by growth form in Tables 3, 4 and 5. A total of 61 species were recognized in the reference area, compared to 54 species in NPOP-20, 44 species in SPOP-34, and 43 species in SPOP-35. Not all species recognized in the reclaimed and reference area were captured in the quadrats. Tables A3-6 lists the species measured in each area and the corresponding relative foliar cover, basal cover and frequency (See appendix). Tables A7-10 provides information on the seasonality, origin, and forage value of the species where known (See appendix).

The original seed mixes were comprised of 7-9 species and some of the plants in the pit bottoms probably originated as contaminants. Nonetheless, the large number of species in the pit bottoms relative to the number that were originally seeded indicates that natural seed dispersal processes are operating to change the species composition in the reclaimed areas. For example, several wetland species (i.e., *Cyperus esculentus*, *Echinchloa crusgallii*, *Panicum capillare*, *Populus fremontii*, *Scirpus maritimus*, *Scirpus actutus* , and *Typha latifolia*) have become established in the wet-depressional areas in the pit bottoms. The dominant (D) and subdominant (S) species are designated on Table 3-5 for each area and growth form on the basis of relative foliar cover. Grasses are the dominant life forms followed by forbs and shrubs in all areas, with the exception of SPOP-34, where shrubs have a slightly higher relative cover than forbs. Thus, the general vegetative structure of the reclaimed and reference areas is similar and can be considered grass-shrub communities.

Table 3. List of grass and grass-like species recognized in the reclaimed pit bottoms and reference area in the 1996 vegetation study. Jackpile/Paquate Uranium Mine, Laguna Pueblo, NM.

Scientific Name	Common Name	NPOP-20	SPOP-34	SPOP-35	Ref. Area
Agropyron cristatum	Crested wheatgrass	P	-	-	-
Agropyron smithii	Western wheatgrass	P	P	-	P
Aristida adscensionis	Sixweeks threeawn	-	P	-	P
Aristida purpurea	Purple three-awn	P	P	P	P
Bothriochloa barbinodis	Cane Bluestem	P	P	P	-
Bothriochloa ischaemum	Yellow bluestem	-	-	P	-
Bouteloua barbata	Sixweeks grama	-	-	P	S
Bouteloua curtipendula	Sideoats grama	S	D	D	P
Bouteloua gracilis	Blue grama	D	S	P	P
Bromus commutatus	Hairy brome	-	-	P	-
Cenchrus pauciflorus	Sandbur	-	-	-	P
Chloris virgata	Feather fingergrass	P	P	P	P
Cyperus esculentus	Chufa	-	-	P	P
Echinocloa crusgallii	Barnyard grass	P	P	P	-
Elymus cinereus	Rye	-	P	-	-
Enneapogon desvauxii	Spike pappusgrass	-	-	-	P
Eragrostis arida	Desert lovegrass	P	P	P	P
Eragrostis cilianensis	Stinkgrass	-	-	-	P
Hillaria jamesii	Galleta grass	S	-	-	P
Hordeun pusillum	Little Barley	P	-	P	P
Leptochloa dubia	Green sprangletop	-	P	-	-
Muhlenbergia torreyi	Ring-Muhly	P	P	-	P
Munroa squarrosa	False buffalograss	P	-	-	P
Oryzopsis hymenoides	Indian ricegrass	P	D	S	P
Panicum capillare	Witchgrass	P	P	P	-
Panicum obtusum	Vine mesquite	-	-	-	P
Scirpus actutus	Tule bulrush	P	P	P	-
Scirpus maritimus	Prairie bulrush	P	P	P	-
Schizachyrium scoparium	Little Bluestem	P	P	P	-
Schedonnardus paniculatis	Tumblegrass	P	-	P	-
Setaria pumila	Yellow bristlegrass	P	P	P	-
Sitanion hystrix	Bottlebrush squirreltail	P	-	P	-
Sporobolus airoides	Alkali sacaton	P	P	P	D
Sporobolus contractus	Spike dropseed	P	P	P	P
Sporobolus cryptandrus	Sand dropseed	P	P	P	P
Sporobolus flexuosus	Mesa dropseed	-	-	-	P
Tragus berteronianus	Spike burgrass	-	-	-	P
Typha latifolia	Cattail	-	-	P	-

P = Present; D = Dominant; S = Subdominant with dominance based on foliar cover.

Table 4. List of forb species recognized in the reclaimed pit bottoms and reference area in the 1996 vegetation study. Jackpile/Paquate Uranium Mine, Laguna Pueblo.

Scientific Name	Common Name	NPOP-20	SPOP-34	SPOP-35	Ref. Areas
Anoda cristata	Anoda	-	-	-	-
Ambrosia acanthicarpa	Ragweed	-	-	-	P
Asclepias subverticillata	Poison milkweed	P	P	P	P
Aster pauciflorus	Slender aster	P	P	S	P
Astragalus pattersonii	Patterson milkvetch	P	-	-	-
Astragalus spp.	Locoweed	-	-	-	P
Bahia dissecta	Yellow ragweed	-	-	P	-
Conyza canadensis	Horseweed	P	P	P	-
Dyssodia papposa	Dogweed	P	P	P	P
Euphorbia dentata	Toothed poinsettia	-	-	P	P
Euphorbia heterophylla	Spurge	-	-	-	P
Euphorbia serpyllifolia	Spurge	P	P	P	P
Euphorbia supina	Wooly Spurge	-	S	-	-
Glandularia Wrightii	Wright's verbena	-	-	P	-
Grindelia aphanactis	Curly-cup gumweed	P	P	P	P
Happlopappus spinulosus	Perennial goldenweed	-	P	-	P
Helinathus annus	Annual sunflower	P	P	P	-
Helenium autumnale	Western sneezeweed	P	-	-	P
Kochia scoparia	Kochia	S	P	D	P
Kuhnia eupatoroides	False boneset	P	-	-	-
Melilotus alba	White sweet clover	P	-	-	-
Melilotus officinalis	Yellow sweet clover	D	D	P	-
Mirablis glabra	Desert four-o'-clock	-	-	-	P
Leguminosae sp.	Unknown legume	-	-	-	P
Pectis angustifolia	Lemonweed, Cugpo	-	-	-	P
Physalis virginia	Ground-cherry	P	-	-	P
Portulaca oleracea	Purslane	P	P	P	D
Portulca mundula	Rose purslane	-	-	-	P
Proboscidea parviflora	Devil's claw	-	-	-	P
Ratibida tagetes	Coneflower	-	-	P	-
Sanvitalia albertii	Sanvitalia	-	-	-	P
Salsola kali	Tumbleweed	P	P	P	S
Salvia reflexa	Rocky Mountain sage	P	-	P	P
Senecio spartoides	Many-headed groundsel	-	P	P	P
Senecio sp. -1	Unknown senecio ?	P	P	P	-
Senecio sp. -2	Unknown senecio ?	P	P	P	-
Solanum elaeagnifloium	Nightshade	P	-	P	P
Sphaeralcea angustifolia	Narrow-leaf globemallow	P	P	P	P
Verbesina enceloides	Cowpen daisy	-	-	P	P
Xanthium strumarium	Cocklebur	P	-	P	-

P = Present; D = Dominant; S = Subdominant with dominance based on foliar cover.

Table 5. List of shrub, tree, and cacti species recognized in the reclaimed pit bottoms and reference area in the 1996 vegetation study. Jackpile/Paquate Uranium Mine, Laguna Pueblo, NM.

Scientific Name	Common Name	NPOP-20	SPOP-34	SPOP-35	Ref. Areas
Artemisia bigelovii	Bigelow sage	-	-	P	-
Artemisia ludoviciana	Louisianna wormwood	-	-	-	P
Atriplex canescens	Four-wing saltbush	D	D	D	D
Chrysothamnus nauseosus	Rubber rabbitbush	P	P	S	S
Elaegnus angustifolia	Russian-olive	P	-	-	-
Eurotia lanata	Winterfat	P	S	P	P
Gutierrezia sarothrae	Broom snakeweed	S	P	P	P
Juniperus monosperma	One-seed juniper	-	-	-	P
Kochia americana	Red-sage	P	-	-	-
Lycium pallidum	Wolfberry	-	-	-	P
Opuntia clavata	Dagger cholla	-	-	-	P
Optunia imbricata	Tree cholla	-	-	-	P
Optunia polyacantha	Prickly pear	-	-	-	P
Populus fremontii	Fremont's cottonwood	-	P	-	-
Sarcobatus vermiculatus	Greasewood	-	-	-	P
Suaeda suffrutescens	Desert seepweed	-	-	P	-
Tamarix chinensis	Salt-cedar	P	P	P	P
Ulmus parvifolia	Chinese elm	P	-	-	-

P = Present; D = Dominant; S = Subdominant with dominance based on foliar cover.

3.2 Total Foliar Cover

Total foliar cover and the cover associated with exposed surface rock, litter, and bare soil in the reclaimed and reference area are listed in Table 6. Foliar cover is one of the primary success criteria and the data meet the target level of statistical reliability (Table 6). The SPOP-34 and SPOP-35 pit bottoms meet the ROD success criteria for total foliar cover, since their mean cover is within 90% of the reference area. The total foliar cover in the NPOP-20 pit bottom is about 65% of the reference area and does not meet the ROD success criteria at face value. However, total foliar cover includes the contribution from all species regardless of their desirability. Annual grasses and low value forage grasses are the dominant grass life forms in the reference area, whereas more desirable perennial grasses dominate the pit bottoms (Table 3). Thus, the lower apparent total cover in the NPOP-20 pit bottom is deceptive with respect to reclamation success, since vegetative composition in the reference area is not necessarily optimal. It should be noted that foliar cover varies with the annual and seasonal distribution of precipitation. Thus, significant variations in foliar cover may occur from year to year as the growth of both annual and perennial plants changes in response to the prevailing climatic conditions.

Table 6. Mean Total foliar cover and exposed surface rock, litter, and bare soil for the reclaimed pit bottoms and reference area. Jackpile/Paquate Uranium Mine, Laguna, NM.

	Percent Total Cover				Foliar Cover Statistical Measures				
Location	Foliar	Rock	Litter	Bare Soil	S.D.	90% C.I.	n	N_{min}	% Mean Est.
NPOP-20	32.9	1.2	0.6	65.3	23.2	32.9 ± 2.6	128	82	90%
SPOP-34	47.6	1.5	1.7	49.2	23.6	47.6 ± 3.9	60	41	90%
SPOP-35	47.4	0.5	1.1	50.1	25.4	47.4 ± 4.2	60	48	90%
Ref. Areas	50.4	0.5	4.2	44.8	21.9	50.4 ± 2.6	120	31	90%

3.3 Basal Cover

Basal cover of perennial plants is less affected by climatic variables and provides a better basis for evaluating reclamation success, than foliar cover. The vegetative, rock. and litter basal cover and corresponding bare soil estimates for the reclaimed and reference areas are listed in Table 7. The basal cover estimates meet the statistical adequacy requirements with the exception of the SPOP-35 pit bottom. The basal cover estimates in SPOP-35 are reliable at the 90% confidence limit within plus or minus 15% of the mean. The basal cover in the SPOP-34 pit bottom exceeds the reference area basal and meets the ROD success criteria. The total vegetative basal cover in the NPOP-20 (71%) and SPOP-35 (85%) pit bottoms is less than 90% of the reference level. Like foliar cover, the mean basal cover in the reference area is strongly influenced by annual grasses that are generally considered less desirable reclamation species. Figure 8 shows the vegetative basal cover associated with annual and perennial grasses, forbs, and shrubs in the reclaimed and reference areas. The relatively high proportion annual grasses in the reference area compared to the reclaimed areas is clearly evident in Figure 8A .

It is important to recognize the contribution of the annual grasses since their cover and frequency vary with the prevailing weather conditions. The dominant annual grasses in the reference area are warm-season species (i.e., Sixweeks grama, False buffalograss, and Sixweeks threeawn) that were probably influenced by the above normal summer precipitation of 1996. These species are expected to occur at a lower frequency in years with less summer precipitation, thus, they do not represent stable components of the ecosystem. The basal cover data for perennial grasses provides a better comparison of the reclamation success than total vegetative basal cover (Fig. 8B). On the basis of perennial grass cover, SPOP-35 meets the ROD reclamation standard and NPOP-20 is within about five percent of the standard. The exact contribution of annual grass species to total foliar cover is difficult to quantify, but the affect is similar to basal cover. Thus, the total cover data presented earlier probably do not fairly represent the status of the reclaimed areas relative to the reference area, and the reclamation can be considered better than is implied by the simple comparison of the total foliar cover data.

Table 7. Mean basal cover for the reclaimed pit bottoms and reference area at the Jackpile/Paquate Uranium Mine.

	Percent Basal Cover				Vegetative Basal Cover Statistical Measures				
Location	Vegetative	Rock	Litter	Bare Soil	S.D.	90% C.I.	n	N_{min}	% Mean Est.
NPOP-20	5.3	1.9	0.8	92.0	3.9	5.3 ± 0.4	128	89	90%
SPOP-34	7.6	1.5	1.7	89.2	3.6	7.6 ± 0.6	60	38	90%
SPOP-35	6.3	0.5	0.2	91.2	4.9	4.9 ± 0.8	60	102	85%
Ref. Areas	7.4	0.6	7.9	84.1	4.9	7.4 ± 0.6	120	72	90%

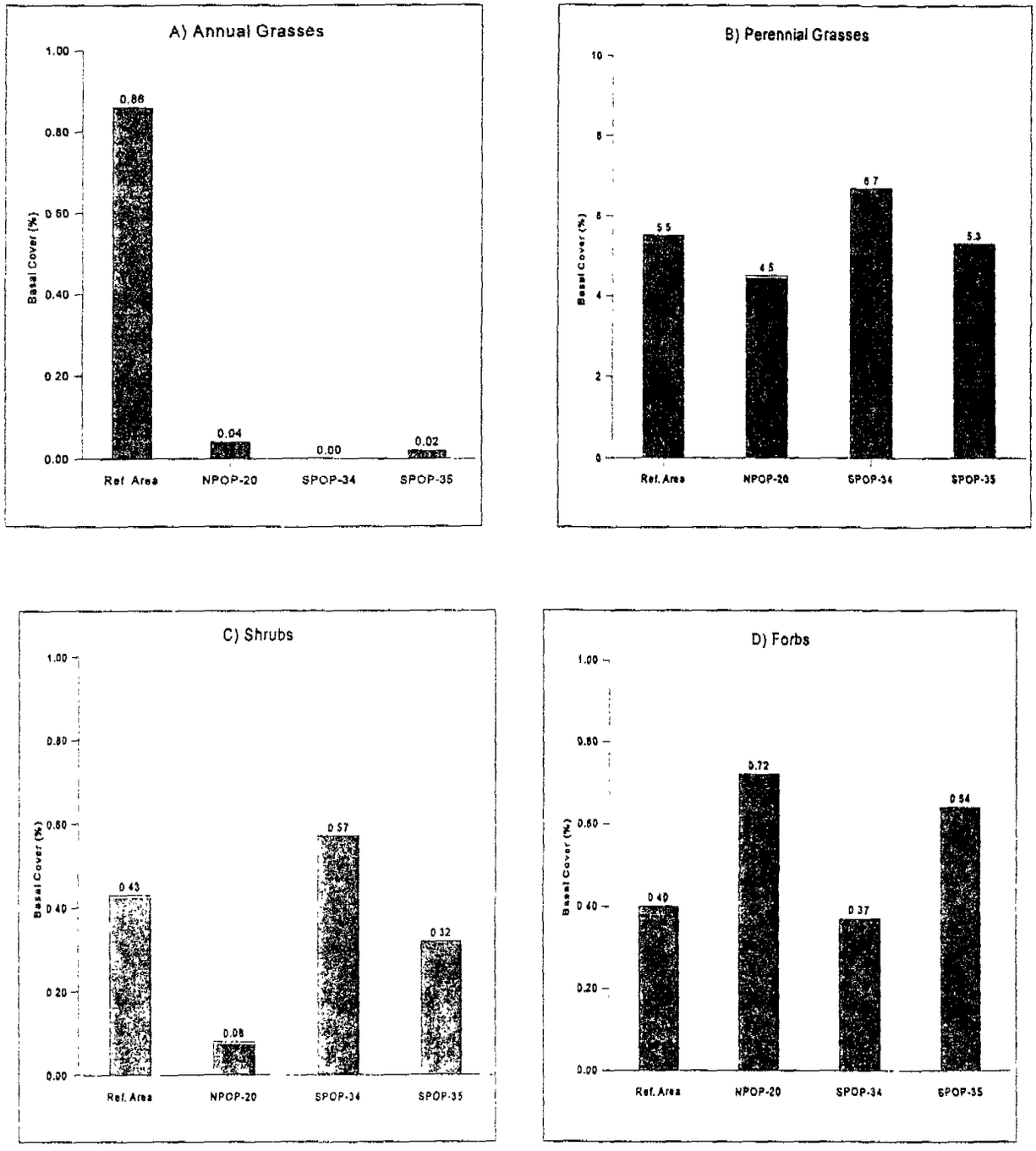


Figure 8. Basal cover relationships in the reclaimed pit bottoms and reference area at the Jackpile/Paquate uranium mine. A) Annual grasses, B) Perennial grasses, C) Shrubs, and D) Forbs.

3.4 Annual Production of Perennial Grasses

The annual production of perennial grasses in the reclaimed pit bottoms exceeds the production in the reference area. The mean annual production in the reclaimed pit bottoms is 1.5-2.4 times the reference area production (Table. 8). The reclaimed pit bottoms are considered to meet the ROD success criteria of 90% of the mean, since the annual productivity is clearly higher than in the reference area (Fig. 9). Sample adequacy was not achieved in the reclaimed or reference areas because of time and budgetary constraints and the statistical reliability of the productivity estimates is lower than that for foliar and basal cover. The upper and lower confidence intervals for the reference area and NPOP-20 overlap suggesting a slight possibility that the NPOP-20 pit bottom may not meet the ROD success criteria. It should be recognized that the production measure is based only on perennial grasses and the total aboveground biomass is higher than is portrayed in this data. The high productivity of the pit bottoms is attributed to the predominance of high yielding perennial grasses (i.e., Blue grama, Sideoats grama, Indian ricegrass) in comparison to the reference area that had a higher proportion of lower yielding species like Purple threeawn and Ring muhly. Alkali sacaton was the primary species contributing to the production estimate in the reference area.

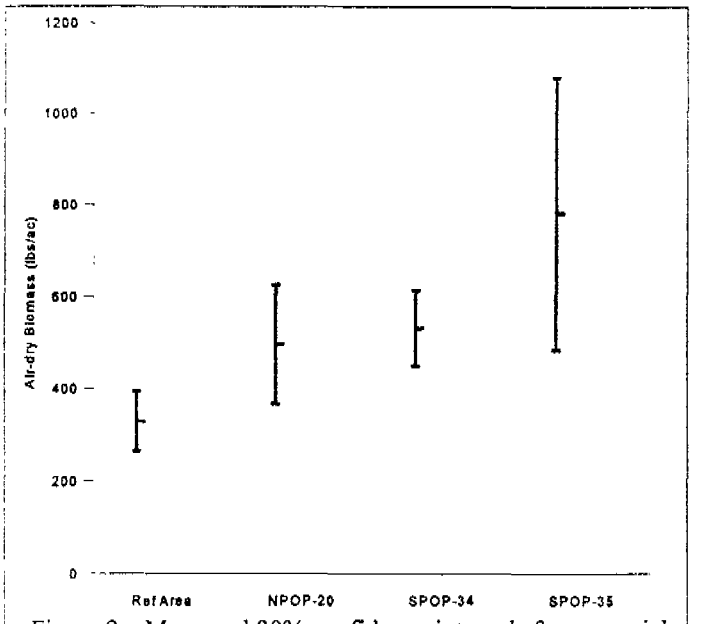


Figure 9. Mean and 90% confidence intervals for perennial grass biomass production in the reclaimed pit bottoms and reference area.

Table 8. Annual aboveground biomass production of perennial grasses in the reclaimed pit bottoms and reference area at the Jackpile/Paquate Uranium Mine.

	Mean	Range		Biomass Production Statistical Measures				
Location	Production	Low	High	S.D.	90% C.I.	n	N_{min}	% Mean Est.
NPOP-20	496	0	2094	519	496 ± 129	28	189	75%
SPOP-34	531	250	808	189	531 ± 82	10	24	85%
SPOP-35	783	0	2087	687	783 ± 298	10	145	65%
Ref. Areas	328	0	862	218	328 ± 65	20	78	80%

3.5 Frequency and Density

The mean plant density and frequency are listed in the Table 9. Density is the average number of individual plants that occur in a given area. Frequency is defined as the percent occurrence of a species in a series of samples (Daubenmire, 1968). The density measure does not contain information on the size or desirability of the vegetation, and is of limited value when comparing stands that are compositionally different. In contrast, the frequency data may be displayed by growth form or seasonality and is a more meaningful comparative parameter than plant density.

The average plant density is much higher in the reference area, than in the reclaimed pit bottoms. The high plant density in the reference area is associated with the occurrence of annual grasses and decadent Alkali sacaton plants. The centers of the older Alkali sacaton plants have died and the plants have tillered extensively. The tillered stems of the Alkali sacaton were counted as individuals, rather than the stems of an individual.. The grasses in the reclaimed areas were less affected by this process, because of species and age differences. Thus, the higher density in the reference area is partially a function of the annual grasses and a measurement artifact related to the growth form of the Alkali sacaton. Figure 10 illustrates the plant composition by growth form in the reclaimed and reference areas, however, it should be recognized that the perennial grass values are still affected by the measurement methods. On a growth form-frequency basis, the reclaimed areas are dominated by perennial grasses and forbs, and compare favorably to the reference area. The dominant forbs in the reclaimed pit bottoms (Kochia, Tumbleweed, and Yellow sweet clover) are expected to decrease in frequency with time. Although, the more desirable yellow sweet clover may persist for a significant period of time based on observations at other reclamation sites in New Mexico.

Table 9. Plant frequency and density relationships in the reclaimed pit bottoms and reference area (1996).

	Mean Frequency (%)				Mean	Density Statistical Measures				
Location	P. Grass	A. Grass	Shrubs	Forbs	Density	S.D.	90% C.I.	n	N_{min}	% Mean Est.
NPOP-20	43.2	1.3	1.0	54.5	22.6	26.2	22.6 ± 3.0	128	221	85%
SPOP-34	60.2	0.0	10.7	29.1	15.0	12.1	15.0 ± 2.0	60	109	85%
SPOP-35	36.3	10.6	2.1	50.9	22.3	32.3	22.3 ± 5.4	352	145	75%
Ref. Area	49.6	33.3	2.7	13.4	38.0	26.4	38.0 ± 3.1	120	79	90%

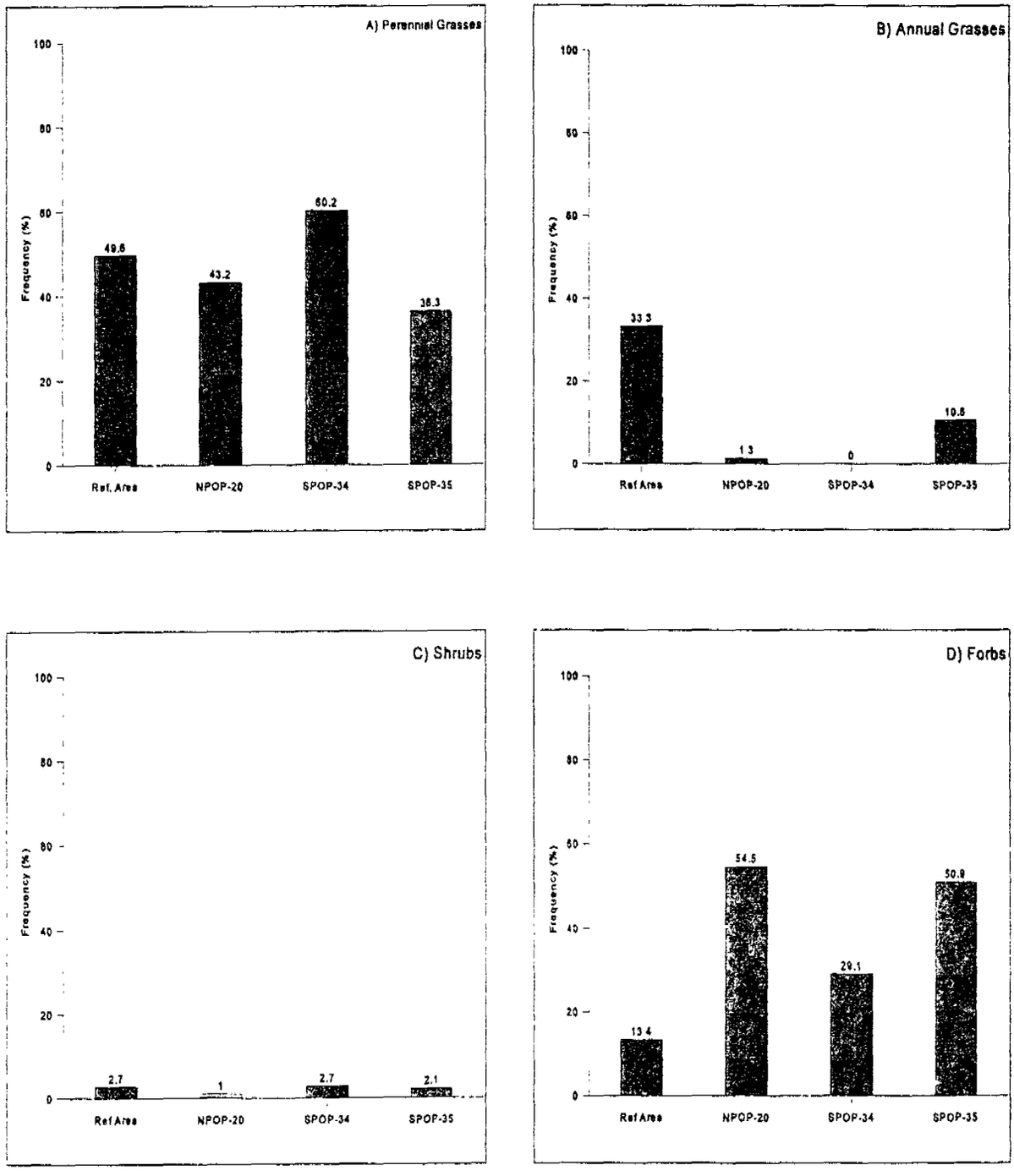


Figure 10. Plant frequency by growth form in the reclaimed pit bottoms and references areas; A) Perennial grasses, B) Annual grasses, C) shrubs, and D) Forbs.

4.0 Literature Cited

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5.0 Appendix

Accessory Tables and Figures

Table A1. Abbreviated soil descriptions for the reclaimed pit bottoms at the Jackpile/Paquate Uranium Mine.

Site	Depth	Material	Munsell Color		USDA Texture	Co. Frags	HCl Eff.	Roots
			Dry	Moist				
	in.				class	%		
				NPOP-20				
20TP1	0-31	TD	2.5Y 5/2	2.5Y 4/2	SiCL	--	es	2vf, 1f,m,co
	31-52	MS	5Y 5/1	5Y 2.5/1	SCL	65	eo	1vf,f
	52-60	JPSS	10YR 8/1	10YR 6/1	SL	35	eo	none
20TP2	0-29	TD	2.5Y 6/2	2.5Y 5/2	CL/C	5	es	2vf; 1f,m,co
	29-42	MS	5Y 5/1	5Y 3/1	CL	60	eo	2vf; 1f,f,co
	42-60	JPSS	10YR 8/1	10YR 7/1	SL	40	eo	none
20TP3	0-34	TD	2.5Y 6/3	2.5Y 5/3	SiC	5	es	2vf; 1f,m,co
	34-52	MS	5Y 5/3	5Y 5/1	CL	60	eo	1vf,f,m,co
	52-60	JPSS	10YR 8/1	10YR 7/1	SL	40	eo	none
20TP4	0-19	TD	10YR 6/3	10YR 5/3	SL	30	es	1vf,f,m,co
	19-36	MS	5Y 5/3	5Y 5/1	CL	60	eo/ev	1vf,f,m,co
	36-60	JPSS	10YR 7/1	10YR 6/1	SL	30	eo	none
20TP5	0-18	TD	10YR 6/4	10YR 5/4	SiCL	--	es	1vf,f,m,co
	18-39	TD	2.5Y 6/4	2.5Y 5/3	SiCL	10	e	1vf,f,m,co
	39-60	MS	5Y 5/1	5Y 3/1	SCL	65	eo	1vf,f,m,co
20TP6	0-20	TD	10YR 5/3	10YR 4/3	CL	5	es	1vf,f,m,co
	20-27	JPSS	10YR 7/2	10YR 6/2	SL	15	eo	1vf
	27-60	TD	10YR 4/1	10YR 3/1	CL	20	es	1vf
				SPOP-34				
34TP1	0-30	TD	10YR 6/4	10YR 5/4	L	40	es	3vf; 2f;1m,co
	30-60	MS	5Y 5/1	5Y 3/1	CL	65	es-	2vf; 1f,m,co
34TP2	0-24	TD	2.5Y 6/3	2.5Y 5/3	CL	30	es	2vf; 1f,m,co
	24-60	MS	5Y 5/1	5Y 3/1	C	65	es-	2vf; 1f,m,co
34TP3	0-22	TD	2.5Y 6/3	2.5Y 5/3	CL	30	es	2vf; 1f,m,co
	22-31	MS	5Y 5/1	5Y 3/1	C	65	es-	1vf
	31-60	MS	5Y 6/1	5Y 5/1	VFSL	75	eo	1vf
			Jarosite, gypsum, variegated 7.5YR 4/4 and 10YR 6/6 in 31-60" layer.					
				SPOP-35				
35TP1	0-29	TD	2.5Y 6/2	2.5Y 5\2	SiCl	<5	es	3vf; 2f;1m,co
	29-60	JPSS	10YR 8/1	10YR 7/1	CoSL	65	eo	none
35TP2	0-31	TD	2.5Y 6/2	2.5Y 5/2	L	<5	e	1vf-f
	31-60	TD	10YR 6/4	10YR 5/4	L	<5	es	1vf-f
35TP3	0-37	TD	2.5Y 6/2	2.5Y 5/2	SCL	5	es	2vf, 1f
	37-60	MS	5Y 5/1	5Y 3/1	C	65	eo	1vf-f

TD = topdressing; MS = Mancos shale; JPSS = Jackpile sandstone. Other abbreviations according to the Soil Survey Staff (1993).

Table A2. Abbreviated soil descriptions of the pit bottom-reference areas at the Jackpile/Paquate Uranium Mine.

Site	Depth	Horizon	Munsell Color		USDA Texture	Co. Frags	HCl Eff.	Structure
			Dry	Moist				
	in.				class	%		
REF-1	0-10	A	10YR 6/3	10YR 4/2	FSL	<5	e	m
	10-20	AB	10YR 6/2	10YR 4/3	FSL	<5	e	1-f-sbk
	20-48	Btk	10YR 5/2	10YR 3/2	L	<5	es	2-f-sbk
	48-60	C	10YR 6/2	10YR 4/2	L	<5	es	Augered
REF-2	0-1	A	10YR 6/3	10YR 4/3	FSL	<5	e	lo
Plot 15	1-12	A2	10YR 5/2	10YR 3/2	SL	<5	e	1-f-sbk
	12-34	Btk	10YR 6/2	10YR 4/2	SL	<5	es	2-f-sbk
	34-55	Ab	10YR 4/2	10YR 3/2	C	<5	es	Augered
	55-60	C	10YR 6/2	10YR 4/2	L	<5	es	Augered
REF-2	0-7	A	10YR 6/3	10YR 4/3	FSL	<5	e	m
Plot 7	7-24	C1	10YR 6/3	10YR 4/3	FSL	<5	es	m
	24-45	C2	10YR 6/2	10YR 4/2	CL	<5	es	Augered
	45-60	C3	10YR 5/2	10YR 3/3	C	<5	es	Augered

Table A3. Species list, relative foliar cover, vegetative basal cover, and plant frequency for the reference area.

Scientific Name	Common Name	Relative Foliar Cover %	Basal Cover %	Plant Frequency %	Abbrev. Code
Grasses/Grass-like					
Agropyron smithii	Western wheatgrass	0.25	0.02	0.31	AGSM
Aristida adscensionis	Sixweeks threeawn	1.70	0.10	4.51	ARAD
Aristida purpurea	Purple three-awn	2.03	0.43	2.87	ARPU
Bouteloua barbata	Sixweeks grama	9.61	0.45	22.35	BOBA
Bouteloua gracilis	Blue grama	0.45	0.06	0.53	BOGR
Chloris virgata	Feather fingergrass	0.01	0.01	0.04	CHVI
Cyperus esculentus	Chufa	0.13	0.01	0.56	CYES
Eragrostis cilianensis	Stinkgrass	0.01	0.01	0.09	ERCI
Hillaria jamesii	Galleta grass	2.58	0.34	5.87	HIJA
Muhlenbergia torreyi	Ring-Muhly	2.79	1.12	10.63	MUTO
Munroa squarrosa	False buffalograss	3.06	0.28	6.11	MUSQ
Oryzopsis hymenoides	Indian ricegrass	0.41	0.05	0.15	ORHY
Panicum obtusum	Vine mesquite	0.06	<0.01	0.18	POAB
Sporobolus airoides	Alkali sacaton	18.55	3.01	19.94	SPAI
Sporobolus contractus	Spike dropseed	1.01	0.10	1.23	SPCO
Sporobolus cryptandrus	Sand dropseed	3.88	0.33	6.97	SPCR
Sporobolus flexuosus	Mesa dropseed	0.37	0.03	0.88	SPFL
Tragus berteronianus	Spike burgrass	0.02	0.01	0.15	TRBE
Shrubs/Trees					
Atriplex canescens	Four-wing saltbush	5.47	0.23	1.16	ATCA
Chrysothamnus nauseosus	Rubber rabbitbush	1.35	0.04	0.07	CHNA
Eurotia lanata	Winterfat	0.02	<0.01	0.02	EULA
Gutierrezia sarothrae	Broom snakeweed	0.62	0.09	1.18	GUSA
Opuntia clavata	Dagger cholla	0.02	<0.01	0.04	OPCL
Optunia imbricata	Tree cholla	0.01	0.01	0.04	OPIM
Optunia polyacantha	Prickly pear	0.30	0.05	0.20	OPPO
Sarcobatus vermiculatus	Greasewood	0.10	<0.01	0.02	SAVE
Forbs					
Anoda cristata	Anoda	0.10	<0.01	0.02	ANCR
Aster pauciflorus	Slender aster	0.02	<0.01	0.02	ASPA-1
Asclepias subverticillata	Poison milkweed	<0.01	<0.01	0.02	ASSU
Astragalus spp.	Locoweed	0.01	0.01	0.07	ASTRG
serpyllifolia	Spurge	0.05	0.03	6.64	EUSE
Happlopappus spinulosus	Perennial goldenweed	0.15	0.03	0.18	HASP
Kochia scoparia	Kochia	0.23	0.02	0.48	KOSC
Pectis angustifolia	Lemonweed, Cugpo	0.20	0.02	0.90	PEAN
Portulaca oleracea	Purslane	5.89	0.17	4.38	POOL
Portulca mundula	Rose purslane	<0.01	<0.01	0.02	POMU
Proboscidea parviflora	Devil's claw	<0.01	<0.01	0.02	PRPA
Sanvitalia albertii	Sanvitalia	0.20	0.02	0.11	SAAL
Salsola kali	Tumbleweed	0.40	0.05	0.39	SAKA
Senecio spartoides	Many-headed groundsel	0.17	<0.01	0.02	SESP
Solanum elaeagnifloium	Nightshade	0.10	0.03	0.39	SOEL
Sphaeralcea angustifolia	Narrow-leaf globemallow	0.03	0.01	0.09	SPAN
Verbesina enceloides	Cowpen daisy	0.03	<0.01	0.02	VEEN

Table A4. Relative foliar cover, vegetative basal cover, and plant frequency for the NPOP-20 study area.

Scientific Name	Common Name	Relative Foliar Cover	Basal Cover	Plant Frequency	Abbrev.
Grass and Grass-like		%	%	%	Code
Agropyron cristatum	Crested wheatgrass	0.06	0.02	0.03	AGCR
Agropyron smithii	Western wheatgrass	1.83	0.33	8.42	AGSM
Aristida purpurea	Purple three-awn	0.07	0.03	0.55	ARPU
Bouteloua curtipendula	Sideoats gramma	4.74	0.98	4.94	BOCU
Bouteloua gracilis	Blue gramma	5.09	0.88	5.92	BOGR
Chloris virgata	Feather fingergrass	0.34	0.02	0.49	CHVI
Echinocloa crusgallii	Barnyard grass	0.06	<0.01	0.10	ECCR
Eragrostis arida	Desert lovegrass	0.04	0.01	0.69	ERAR
Hillaria jamesii	Galleta grass	4.83	0.96	2.77	HIJA
Oryzopsis hymenoides	Indian ricegrass	2.73	0.42	2.63	ORHY
Schizachyrium scoparium	Little Bluestem	0.46	0.09	0.38	SCSC
Schedonnardus paniculatis	Tumblegrass	0.14	0.03	0.31	SCPA
Sitanion hystrix	Bottlebrush squirreltail	0.02	<0.01	0.03	SIHY
Sporobolus airoides	Alkali sacaton	1.64	0.20	0.94	SPAI
Sporobolus cryptandrus	Sand dropseed	3.44	0.57	16.32	SPCR
Shrubs					
Atriplex canescens	Four-wing saltbush	0.93	0.03	0.28	ATCA
Chrysothamnus nauseosus	Rubber rabbitbush	0.27	0.01	0.07	CHNA
Gutierrezia sarothrae	Broom snakeweed	0.31	0.04	0.62	GUSA
Forbs					
Aster pauciflorus	Slender aster	0.24	0.02	0.21	ASPA-1
Astragalus pattersonii	Patterson milkvetch	0.05	0.01	0.31	ASPA-2
Asclepias subverticillata	Poison milkweed	0.08	0.03	0.80	ASSU
Euphorbia serpyllifolia	Spurge	0.13	0.03	0.83	EUSE
Kochia scoparia	Kochia	2.57	0.16	29.83	KOSC
Melilotus alba	White sweet clover	0.01	0.01	0.07	MEAL
Melilotus officinalis	Yellow sweet clover	5.18	0.31	16.07	MEOF
Physalis virginia	Ground-cherry	0.02	<0.01	0.03	PHVI
Portulaca oleracea	Common purslane	0.02	<0.01	0.07	POOL
Salsola kali	Tumbleweed	1.23	0.09	4.02	SAKA
Salvia reflexa	Rocky Mountain sage	0.05	0.01	0.28	SARE
Senecio sp.	Unknown Forb	0.24	0.01	1.42	UNK-SE
Solanum elaeagnifloium	Nightshade	0.03	0.02	0.42	SOEL
Sphaeralcea angustifolia	Narrow-leaf globemallow	0.03	<0.01	0.14	SPAN

Table A5. Relative foliar cover, vegetative basal cover, and plant frequency for the SPOP-35 study area

Scientific Name	Common Name	Relative Foliar Cover	Basal Cover	Plant Frequency	Abbrev.
		%	%	%	Code
Grasses/Grass-like					
Agropyron smithii	Western wheatgrass	1.28	0.20	3.75	AGSM
Aristida purpurea	Purple three-awn	0.07	0.01	0.07	ARPU
Bothriochloa barbinodis	Cane Bluestem	0.03	0.01	0.07	BOBA-1
Bouteloua curtipendula	Sideoats grama	15.75	2.57	9.74	BOCU
Bouteloua gracilis	Blue grama	6.22	0.56	3.82	BOGR
Bromus commutatus	Hairy brome	0.01	0.01	0.52	BRCO
Hordeun pusillum	Little Barley	0.97	0.11	10.11	HOPU
Oryzopsis hymenoides	Indian ricegrass	10.88	1.26	6.14	ORHY
Schedonnardus paniculatis	Tumblegrass	0.24	0.04	2.77	SCPA
Schizachyrium scoparium	Little Bluestem	0.25	0.05	0.22	SCSC
Sitanion hystrix	Bottlebrush squirreltail	0.13	0.01	0.07	SIHY
Sporobolus airoides	Alkali sacaton	3.41	0.32	1.65	SPAI
Sporobolus cryptandrus	Sand dropseed	1.79	0.28	8.01	SPCR
Shrubs					
Artemisia bigelovii	Bigelow sage	0.16	0.02	0.15	ARBI
Atriplex canescens	Four-wing saltbush	6.38	0.16	1.05	ATCA
Chrysothamnus nauseosus	Rubber rabbitbush	4.88	0.12	0.67	CHNA
Eurotia lanata	Winterfat	0.40	0.02	0.22	EULA
Forbs					
Aster pauciflorus	Slender aster	1.20	0.03	0.37	ASPA-1
Bahia dissecta	Yellow ragweed	0.03	0.01	0.15	BADI
Dyssodia papposa	Dogweed	0.01	0.01	0.07	DYPA
Euphorbia dentata	Toothed poinsettia	0.16	0.02	0.52	EUDE
Euphorbia serpyllifolia	Spurge	0.05	0.03	0.15	EUSE
Grindelia aphanactis	Curly-cup gumweed	0.50	0.01	0.30	GRAP
Kochia scoparia	Kochia	3.10	0.25	33.93	KOSC
Melilotus officinalis	Yellow sweet clover	1.00	0.06	2.47	MEOF
Salsola kali	Tumbleweed	0.01	0.01	0.07	SAKA
Salvia reflexa	Rocky Mountain Sage	0.07	0.01	0.07	SARE
Senecio spp.	Unknown senecio species ?	0.89	0.16	12.21	UNK-Se
Sphaeralcea angustifolia	Narrow-leaf globemallow	0.28	0.03	0.45	SPAN
Verbesina enceloides	Cowpen daisy	0.21	0.01	0.15	VEEN

Table A6. Relative foliar cover, vegetative basal cover, and plant frequency for the SPOP-34 study area

Scientific Name	Common Name	Relative Foliar Cover %	Basal Cover %	Plant Frequency %	Abbrev. Code
Grasses/Grass-like					
Agropyron smithii	Western wheatgrass	0.11	0.03	0.56	AGSM
Aristida purpurea	Purple three-awn	0.24	0.02	0.33	ARPU
Bouteloua curtipendula	Sideoats gramma	16.11	2.98	24.89	BOCU
Bouteloua gracilis	Blue gramma	6.74	0.97	8.44	BOGR
Elymus cinereus	Rye	0.04	0.02	0.11	ELCI
Oryzopsis hymenoides	Indian ricegrass	16.91	2.40	19.56	ORHY
Schizachyrium scoparium	Little Bluestem	0.20	0.06	0.44	SCSC
Sitanion hystrix	Bottlebrush squirreltail	0.03	0.01	0.11	SIHY
Sporobolus airoides	Alkali sacaton	0.01	0.01	0.11	SPAR
Sporobolus cryptandrus	Sand dropseed	1.69	0.23	5.67	SPCR
Shrubs					
Atriplex canescens	Four-wing saltbush	6.95	0.26	3.89	ATCA
Chrysothamnus nauseosus	Rubber rabbitbush	0.53	0.04	0.56	CHNA
Eurotia lanata	Winterfat	2.09	0.26	6.11	EULA
Gutierrezia sarothrae	Broom snakeweed	0.01	0.01	0.11	GUSA
Forbs					
Dyssodia papposa	Dogweed	0.07	0.01	0.22	DYPA
Euphorbia supina	Spurge	0.08	0.03	4.00	EUSU
Kochia scoparia	Kochia	0.05	0.03	0.56	KOSC
Melilotus officinalis	Yellow sweet clover	4.73	0.27	23.67	MEOF
Salsola kali	Tumbleweed	0.03	0.03	0.67	SAKA

Table A7. Plant list and characteristics for shrub, tree, and cacti species identified in the reclaimed Pit Bottoms and Reference Areas. Jackpile/Paquate Uranium Mine vegetation study, Laguna Pueblo.

Scientific Name	Common Name	Duration	Season	Value	Origin
Artemisia bigelovii	Bigelow sage	Per	NA	Unk	Nat
Artemisia ludoviciana	Louisianna wormwood	Per	NA	Unk	Nat
Atriplex canescens	Four-wing saltbush	Per	NA	Good	Nat
Chrysothamnus nauseosus	Rubber rabbitbush	Per	NA	Poor	Nat
Elaegnus angustifolia	Russian-olive	Per	NA	None	Intr
Eurotia lanata	Winterfat	Per	NA	Good	Nat
Gutierrezia sarothrae	Broom snakeweed	Per	NA	Poor	Nat
Juniperus monosperma	One-seed juniper	Per	NA	None	Nat
Kochia americana	Red-sage	Per	NA	Unk	Nat
Lycium pallidum	Wolfberry	Per	NA	None	Nat
Opuntia clavata	Dagger cholla	Per	NA	None	Nat
Optunia imbricata	Tree cholla	Per	NA	None	Nat
Optunia polyacantha	Prickly pear	Per	NA	None	Nat
Populus fremontii	Fremont's cottonwood	Per	NA	None	Nat
Sarcobatus vermiculatus	Greasewood	Per	NA	Poor	Nat
Suaeda suffrutescens	Desert seepweed	Per	NA	Browse	Nat
Tamarix chinensis	Salt-cedar	Per	NA	None	Intr
Ulmus parvifolia	Chinese elm	Per	NA	None	Intr

Per = perennial; Ann = Annual; Value = Forage value for livestock, Unk = unknown; Nat = Native, Intr = introduced

Table A8. Plant list and characteristics for grass and grass-like species identified in the reclaimed Pit Bottoms and Reference Areas. Jackpile/Paquate Uranium Mine vegetation study, Laguna Pueblo.

Scientific Name	Common Name	Duration	Season	Value	Origin
Agropyron cristatum	Crested wheatgrass	Per	Cool	Good	Intr
Agropyron smithii	Western wheatgrass	Per	Cool	Good	Nat
Aristida adscensionis	Sixweeks threeawn	Ann	Warm	Poor	Nat
Aristida purpurea	Purple three-awn	Per	Warm	Poor	Nat
Bothriochloa barbinodis	Cane Bluestem	Per	Warm	Fair	Nat
Bothriochloa ischaemum	Yellow bluestem	Per	Warm	Good	Intr
Bouteloua barbata	Sixweeks grama	Ann	Warm	Poor	Nat
Bouteloua curtipendula	Sideoats grama	Per	Warm	Excel	Nat
Bouteloua gracilis	Blue grama	Per	Warm	Excel	Nat
Bromus commutatus	Hairy brome	Ann	Cool	Fair	Nat
Cenchrus pauciflorus	Sandbur	Ann	Warm	Poor	Nat
Chloris virgata	Feather fingergrass	Ann	Warm	Fair	Nat
Cyperus esculentus	Chufa	Per	Warm	Unk	Nat
Echinocloa crusgallii	Barnyard grass	Ann	Warm	Good	Intr
Elymus cinereus	Rye	Per	Cool	Unk	Nat
Enneapogon desvauxii	Spike pappusgrass	Per	Warm	Poor	Nat
Eragrostis arida	Desert lovegrass	Ann	Warm	Poor	Nat
Eragrostis cilianensis	Stinkgrass	Ann	Warm	Poor	Intr
Hillaria jamesii	Galleta grass	Per	Warm	Good	Nat
Hordeun pusillum	Little Barley	Ann	Cool	Poor	Nat
Leptochloa dubia	Green sprangletop	Per	Warm	Excel	Nat
Muhlenbergia torreyi	Ring-Muhly	Per	Warm	Poor	Nat
Munroa squarrosa	False buffalograss	Ann	Warm	Poor	Nat
Oryzopsis hymenoides	Indian ricegrass	Per	Cool	Good	Nat
Panicum capillare	Witchgrass	Ann	Warm	Poor	Nat
Panicum obtusum	Vine mesquite	Per	Warm	Fair	Nat
Scirpus actutus	Tule bulrush	Per	Cool	Unk	Nat
Scirpus maritimus	Prairie bulrush	Per	Cool	Unk	Nat
Schizachyrium scoparium	Little Bluestem	Per	Warm	Good	Nat
Schedonnardus paniculatis	Tumblegrass	Per	Warm	Poor	Nat
Setaria pumila	Yellow bristlegrass	Ann	Warm	Poor	Nat
Sitanion hystrix	Bottlebrush squirreltail	Per	Warm	Fair	Nat
Sporobolus airoides	Alkali sacaton	Per	Warm	Fair	Nat
Sporobolus contractus	Spike dropseed	Per	Warm	Fair	Nat
Sporobolus cryptandrus	Sand dropseed	Per	Warm	Fair	Nat
Sporobolus flexuosus	Mesa dropseed	Per	Warm	Good	Nat
Tragus berteronianus	Spike burgrass	Ann	Warm	Poor	Intr
Typha latifolia	Cattail	Per	Warm	Unk	Nat

Per = perennial: Ann = Annual; Value = Forage value for livestock, Unk = unknown; Nat = Native, Intr = introduced

Table A9. Plant list and characteristics for forb species identified in the reclaimed Pit Bottoms and Reference Areas. Jackpile/Paquate Uranium Mine vegetation study, Laguna Pueblo.

Scientific Name	Common Name	Duration	Season	Value	Origin
Anoda cristata	Anoda	Per	NA	Unk	Nat
Ambrosia acanthicarpa	Ragweed	Ann	NA	Unk	Nat
Asclepias subverticillata	Poison milkweed	Per	NA	Pos	Nat
Aster pauciflorus	Slender aster	Per	NA	Unk	Nat
Astragalus pattersonii	Patterson milkvetch	Per	NA	Pos	Nat
Astragalus spp.	Locoweed	Per	NA	Pos	Nat
Bahia dissecta	Yellow ragweed	Per	NA	Unk	Nat
Conyza canadensis	Horseweed	Per	NA	Unk	Nat
Dyssodia papposa	Dogweed	Ann	NA	Unk	Nat
Euphorbia dentata	Toothed poinsettia	Ann	NA	Unk	Nat
Euphorbia heterophylla	Spurge	Ann	NA	Unk	Nat
Euphorbia serpyllifolia	Spurge	Ann	NA	Unk	Nat
Euphorbia supina	Wooly Spurge	Ann	NA	Unk	Nat
Glandularia Wrightii	Wright's verbena	Per	NA	Unk	Nat
Grindelia aphanactis	Curly-cup gumweed	Ann	NA	Unk	Nat
Happlopappus spinulosus	Perennial goldenweed	Ann	NA	Unk	Nat
Helinathus annus	Annual sunflower	Ann	NA	Unk	Nat
Helenium autumnale	Western sneezeweed	Per	NA	Unk	Nat
Kochia scoparia	Kochia	Ann	NA	Unk	Intr
Kuhnia eupatoroides	False boneset	Per	NA	Unk	Nat
Melilotus alba	White sweet clover	Per	NA	Good	Intr
Melilotus officinalis	Yellow sweet clover	Per	NA	Good	Intr
Mirablis glabra	Desert four-o'-clock	Per	NA	Unk	Nat
Leguminosae sp.	Unknown legume	Per	NA	Unk	?
Pectis angustifolia	Lemonweed, Cugpo	Ann	NA	Unk	Nat
Physalis virginia	Groundcherry	Per	NA	Unk	Nat
Portulaca oleracea	Purslane	Per	NA	Unk	Nat
Portulca mundula	Rose purslane	Ann	NA	Unk	Nat
Proboscidea parviflora	Devil's claw	Ann	NA	Unk	Nat
Ratibida tagetes	Coneflower	Per	NA	Unk	Nat
Sanvitalia albertii	Sanvitalia	Ann	NA	Unk	Nat
Salsola kali	Tumbleweed	Ann	NA	Poor	Intr
Salvia reflexa	Rocky Mountain sage	Ann	NA	Unk	Nat
Senecio multilobatus	Many-headed groundsel	Per	NA	Pos ?	Nat
Senecio spartoides	Many-headed groundsel	Per	NA	Pos ?	Nat
Senecio sp. -1	Unknown senecio ?	Per	NA	?	Nat
Senecio sp. -2	Unknown senecio ?	Per	NA	?	Nat
Solanum elaeagnifloium	Nightshade	Per	NA	Pos	Nat
Sphaeralcea angustifolia	Narrow-leaf globemallow	Per	NA	Unk	Nat
Verbesina enceloides	Cowpen daisy	Ann	NA	Unk	Nat
Xanthium strumarium	Cocklebur	Ann	NA	Pos ?	Nat

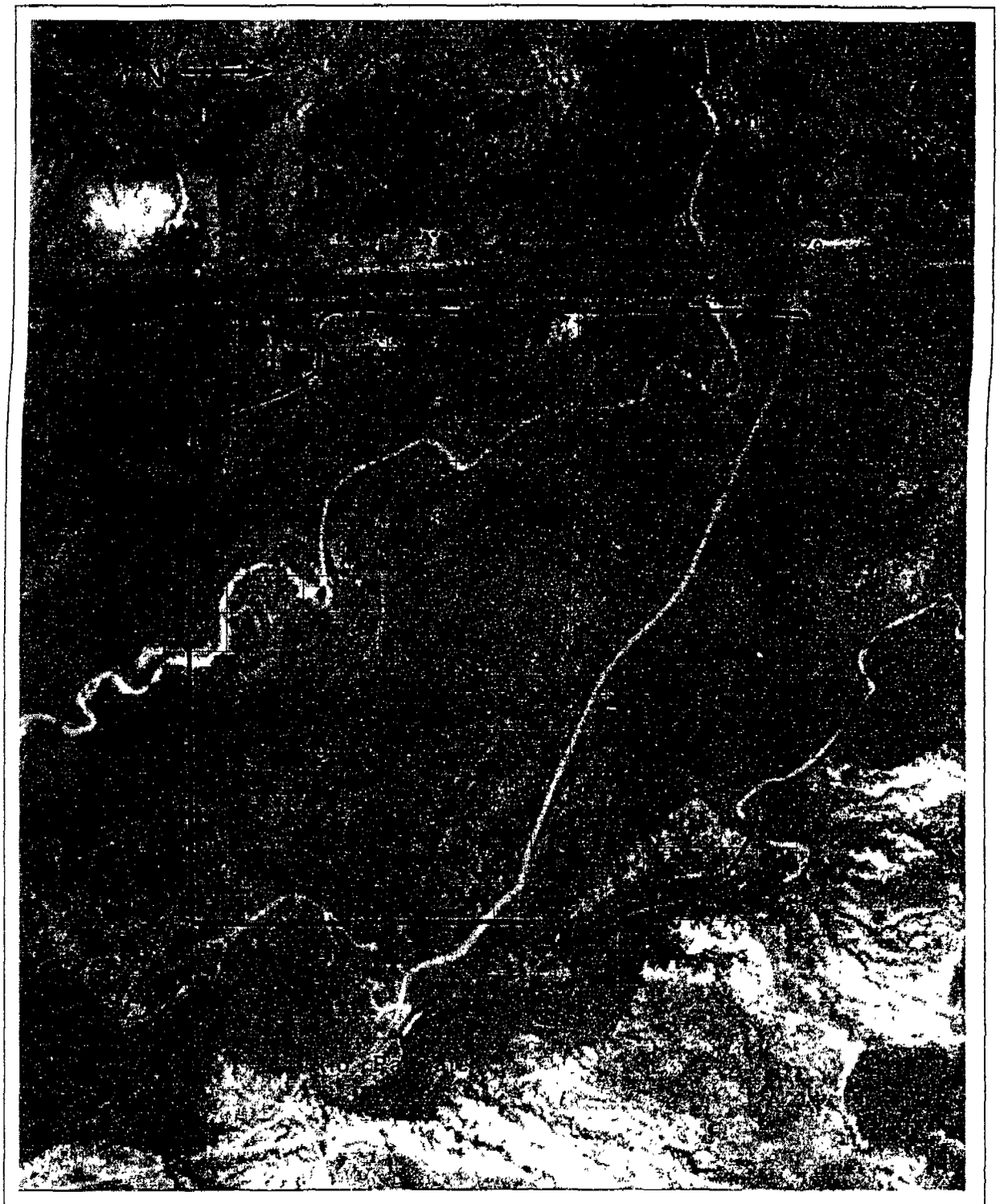
Per = perennial; Ann = Annual; Value = Forage value for livestock, Unk = unknown, Pos = poisonous Nat = Native, Intr = introduced

Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure A1. Plot locations and pit bottom boundary for the North Paquate Open Pit (NPOP-20) . Grid overlay is 38 m (125 ft) square. Approximate scale 1"= 770'.
December 1996	

Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure A2. Plot locations and pit bottom boundary for the South Paquate Open Pit (SPOP-34). Grid overlay is 38 m (125 ft) square. Approximate scale 1" = 500'
December 1996	

Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure A3. Plot locations and pit bottom boundary for the South Paquate Open Pit (SPOP-35). Grid overlay is 38 m (125 ft) square. Approximate scale 1" = 500'.
December 1996	

Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure A4. Vegetation plot locations and boundary for reference area 1, near the old housing area. Grid overlay is 38 m (125 ft) square. Approximate scale 1" = 500'.
December 1996	



Lewis P. Munk, Ph.D., CPSS Soils and Biogeochemistry	Figure A5. Vegetation plot locations and boundary of reference area 2 below Oak Canyon. Grid overlay is 38 m (125 ft) square. Approximate scale 1" = 500'.
December 1996	